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T-38C TRANSITION TO LEAN

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In 2000, the United States Air Force T-38 Avionics Upgrade System Program Office began to pursue Lean initiatives to reduce out-year program cost and delivery risk at the Boeing T-38C Upgrade facility located at Williams Gateway Airport facility in Mesa, Arizona. The T-38 Avionics Upgrade Program production system baseline plan was conventional for legacy aircraft upgrade and modification programs using a mass/craft assembly stationary dock approach. For a successful transition from conventional to Lean production, program management support is critical. The T-38 Program Office in St. Louis, Missouri proposed a four-phase approach to implementation. This approach and the benefits derived from the process are discussed.

The United States Air Force T-38 Avionics Upgrade System Program Office (SPO) expressed a desire in the fourth quarter of CY2000 to pursue lean and efficient initiatives to reduce out-year program cost and delivery risk at the Boeing T-38C Upgrade facility located at Williams Gateway Airport facility in Mesa, Arizona.

Although lean or cellular manufacturing principles can be found in aerospace production facilities across the industry, most activity has centered on new build part fabrication or new build airframe assembly. Legacy aircraft upgrades, modification, maintenance, and overhaul activities have been slower to embrace the Lean culture. Literature suggests that reluctance is due in part to the variability in work content and scope that intuitively would disrupt production system efficiencies based on standardized repeatable work.

The T-38 Avionics Upgrade Program (AUP) production system baseline plan was conventional for legacy aircraft upgrade and modification programs using a mass/craft assembly stationary dock approach. Figure 1 pictorially represents the facility layout with the inherent stationary dock characteristics of people, parts, processes, and test equipment moving to and from aircraft with little resemblance of continuous or straight-line flow.

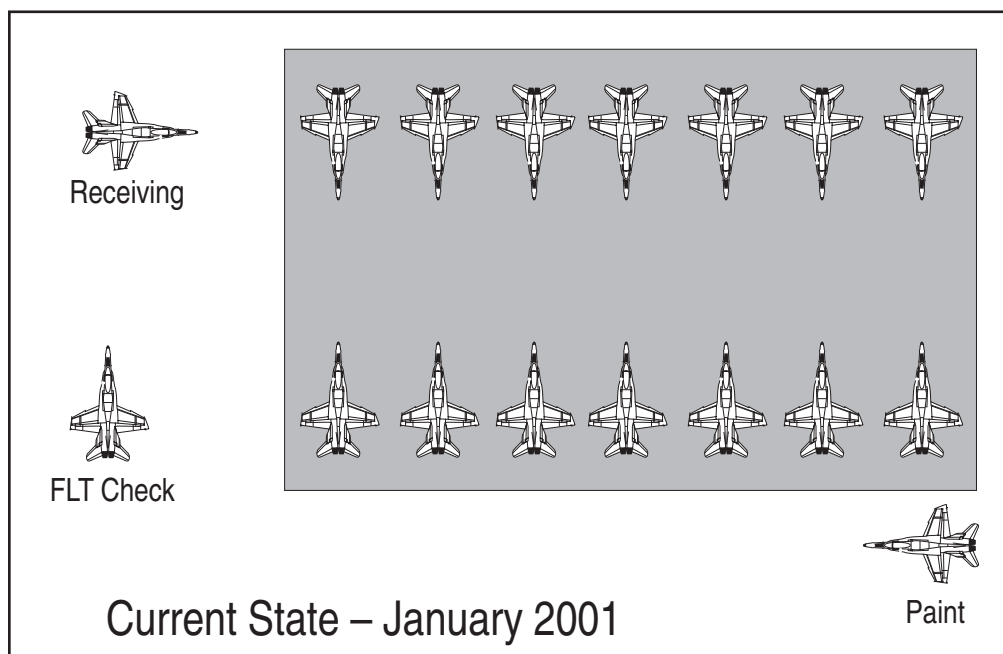


FIGURE 1. MASS/CRAFT ASSEMBLY PRODUCTION SYSTEM

Coincident with a desire to implement Lean principles at the T-38 Avionics Upgrade Production Facility, the upgrade production rate was scheduled to increase from 2 to 7 aircraft per month beginning January 2001 through March 2002.

THE PLAN

The T-38 Program Office in St. Louis, Missouri, responded to the customer's request by providing a statement of work (SOW) based on the systematic deployment of Lean Production Tactics. Figure 2 documents Lean Production Tactics and the evidence, in a context of tangible deliverables, that tactics have been deployed.

The SOW proposed a four-phase approach to Lean implementation.

- | | |
|-----------|---------------------------------|
| Phase I | Mobilize the Commitment to Lean |
| Phase II | Transition Planning |
| Phase III | Implementation |
| Phase IV | Sustaining the Gain |

The SPO funded Phase I of the Boeing proposed SOW in the form of a manufacturing study contract signed on April 18, 2001. The study was intended to determine the applicability and benefits of Lean principles in the T-38 avionics upgrade environment and recommend a go-forward position and strategy.

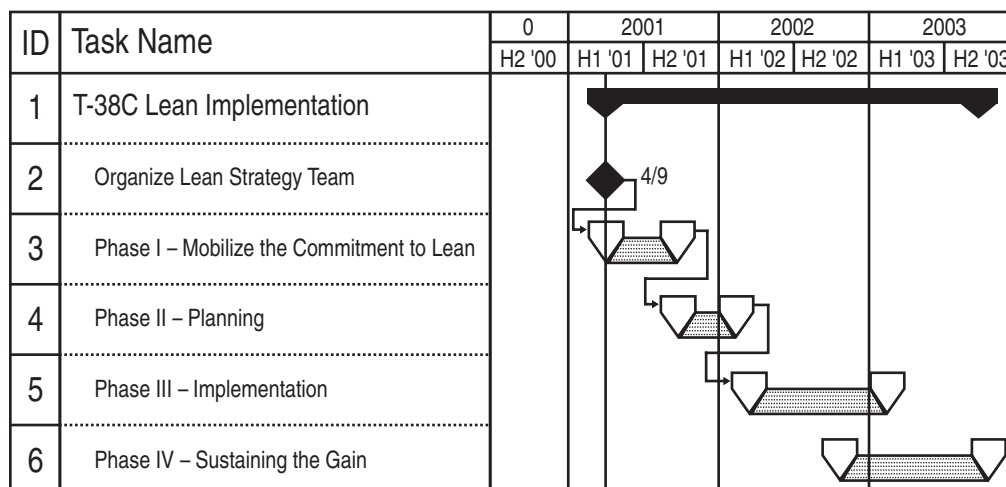
The motivation for both Boeing and the Air Force to study and implement Lean was bottom line financial performance. Boeing would benefit from aggressively

Production Tactics		Deliverable
1	Value Stream Analysis	Current and Future State Maps
2	Balance the Line	All Work Distributed by Shift and Position
3	Standardize Work	Operator Sequence Charts/Bar Charts in Place
4	Visuals in Place	Operator Sequence Charts/Bar Charts Colored to Visually Display Scheduled and Actual Work Status/Quality Metrics/Cost Metrics
5	Point of Use Staging	Jobs Kitted and Staged at Point of Use and Refill Process in Place
6	Feeder Lines	Parallel Worked Moved to Feeder Lines
7	Continuous Flow Line	Product Flow is Pulsed Using an Andon System/Product Moving at TAKT Time

FIGURE 2. LEAN PRODUCTION TACTICS

implementing Lean principles thereby converting cost to earnings for the remaining contracted fixed price options. The Air Force would benefit through substantiated out-year cost base reductions for approximately 50 percent of the production quantities not yet contracted.

Figure 3 presents the proposed SOW Phase sequences and spans. The proposed phase span times were representative of successful activities pursued on similar Boeing Integrated Defense Systems programs and were used to support initial resource and cost estimating.

**FIGURE 3. STATEMENT OF WORK PHASE SEQUENCES**

Funding for Phases II, III, and IV implementation were dependent upon compelling business case substantiation based on the future state value stream performance.

THE APPROACH

Program management support is the critical element of a successful transition from conventional to Lean production. Support materializes in the form of training budgets, a willingness to challenge legacy systems and processes, and a consistent resolve to stay the course for change amid inevitable cultural pushback and challenges. The T-38 AUP was fortunate to have visionary managers within Boeing and the System Program Offices. The objective of Phase I—Mobilize the Commitment to Lean—was to identify potential performance benefits and non-recurring expenditures required to transition the T-38C program to a Lean enterprise.

Lean manufacturing specialists were assigned to the T-38C program in May 2001 in order to begin Phase I activities. St. Louis and Mesa T-38C program personnel, suppliers, and SPO representatives were trained on Lean principles, value stream mapping, and value stream analyses for the purpose of defining the current state product and information flows. The format of training consisted of lectures followed by hands-on simulations reinforcing Lean principles.

A weeklong Production Preparation Process (3P) event lead by Boeing certified Lean practitioners was held at the Williams Gateway Facility in July 2001. The 3P deliverable was a Lean future state value stream upon which a benefit comparison analysis to the current state was performed. Participants included production personnel (60 percent), production support and process owners (30 percent), and management (10 percent). Figure 4 highlights 3P events critical to creating a realistic future state production system.

The three fundamental tenants for the future state T-38 Avionics Upgrade Program Production System were TAKT-timed production paced to meet customer's rate of demand, one-piece flow, and pull production. (In a world of acronyms, TAKT is not one of them. TAKT is a German word loosely translated to a conductor's baton or more closely associated with a drumbeat. TAKT-time is a technique used to coordinate and synchronize certain activities.)



FIGURE 4. PRODUCTION PREPARATION PROCESS EVENTS

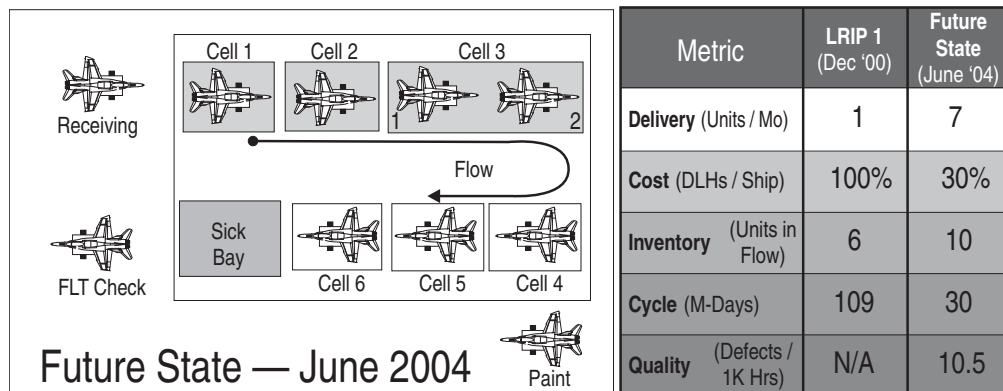
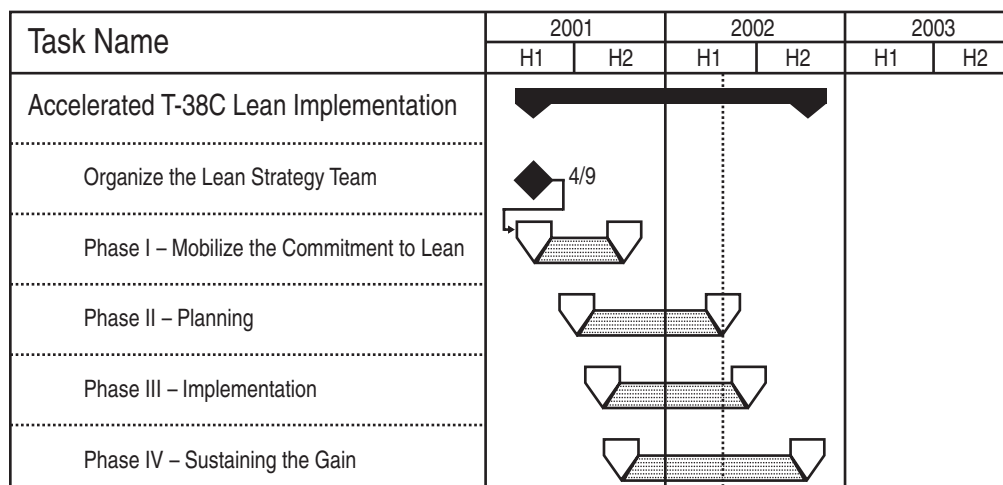
**FIGURE 5.****T-38 FUTURE STATE LAYOUT AND VALUE STREAM PROJECTIONS**

Figure 5 pictorially represents the 3P defined future state facility layout with supporting value stream analyses.

The 3P event and subsequent value stream analyses clearly indicated implementing Lean would result in benefits consistent with the customer's desire to reduce program cost and delivery risk. Boeing leadership, with customer support, chose to accelerate the original SOW Phase II (Planning) and Phase III (Implementation) activities.

Based on the projected future state value stream performance, the Williams Gateway Production Facility accepted the challenge to accommodate the increase in rate 4 to 7 aircraft per month (September 2001 through May 2002) and transform the facility from stationary docks to Lean production cells pulsing at TAKT without increasing production workforce headcount.

**FIGURE 6. ACCELERATED LEAN IMPLEMENTATION**

Early in Phase I, Lean practitioners deployed 6S (5S plus Safety). Immediate performance gains were realized that facilitated the time production personnel were committing to training and Integrated Product Team (IPT) meetings.

Accelerating the Lean implementation phase reduced the transition-planning span and forced a parallel path with implementation. (See Figure 6.) The key to successfully deploying this strategy was employee involvement. Personnel assigned to the production Lean cells met one and one-half hours daily over a period of five weeks with engineering (industrial, manufacturing, liaison), support functions (quality, safety, supply, facilities, business operations, information technology), and management to reorganize work content and precedence, define work cell layout and facility requirements, and set performance goals. (See Figure 7.) The IPT environment, where all parties were stakeholders in Lean cell performance, was critical to meeting the aggressive Lean cell implementation schedule.

THE RESULTS

The health of a Boeing Lean Enterprise Production is measured in the context of five Interdependent Performance Metrics; specifically, Delivery, Cost, Inventory, Cycle, and Quality. Figure 8 quantitatively compares the impact of implementing Lean at the T-38 AUP facility. Low Rate Initial Production (LRIP) 1 values reflect the algebraic average for each performance metric for the first 15 upgraded aircraft produced. The Lean Baseline values reflect the algebraic average for upgraded aircraft delivered in September 2001, prior to deploying any Lean initiatives at the production facility.



FIGURE 7. INTEGRATED PRODUCT TEAM (IPT) MEETING

Metric	LRIP 1 (Dec '00)	Lean Baseline (Sept '01)	Current Status (Aug '03)	Future State (June '04)
Delivery (Units/Mo)	1	4	7	7
Cost (DLHs/Ship)	100%	87%	37%	30%
Inventory (Units in Flow)	6	14	10	10
Cycle (M-Days)	109	64	30	30
Quality (Defects/1K Hrs)	NA	25.3	15.3	10.5

FIGURE 8. T-38C VALUE STREAM PERFORMANCE COMPARISONS

The Current Status metric values reflect the algebraic average for upgraded aircraft delivered in August 2003. The Future State metric values represent the value stream values projected during the July 2001 3P event.

The T-38C Program is well on its way to achieving its future state goals supported by a culture committed to continuous improvement.

Figure 9 presents Direct Labor Hours for delivered upgraded aircraft during the transition to a Lean production system pulsing at TAKT. For reference, an 85 percent learning curve, upon which the production operations were planned, is presented as a trend line. For comparative purposes, Pre- and Post-Lean implementation performance trends are provided.

The noteworthy improvement in DLHs per delivered upgrade is directly attributed to supporting an increase in rate without increasing production center headcount. This accomplishment was made possible through the elimination of the inherent waste associated with the craft/mass assembly production system and its accompanying support systems. The benefits of Lean would be short lived if the concept were simply based on driving the work force to work longer and harder rather than smarter.

Figure 10 reinforces the concept that increased efficiency was achieved through waste elimination. Data plotted on the dual axis graph are the Overtime Plan Target at 6 percent of total production hours (dashed line), percent overtime expended by month to deliver aircraft (vertical bars), and the customer demand by month (solid line). The times each Lean production cell began operation are superposed on the graph and represented by vertical lines.

The workforce was held constant during the period of time when production rate increased from 2 to 7 aircraft per month and the Lean production cells began operations. The overtime trend followed the rate increase until all Lean cells were operational. Overtime rate has remained constant at 2 percent.

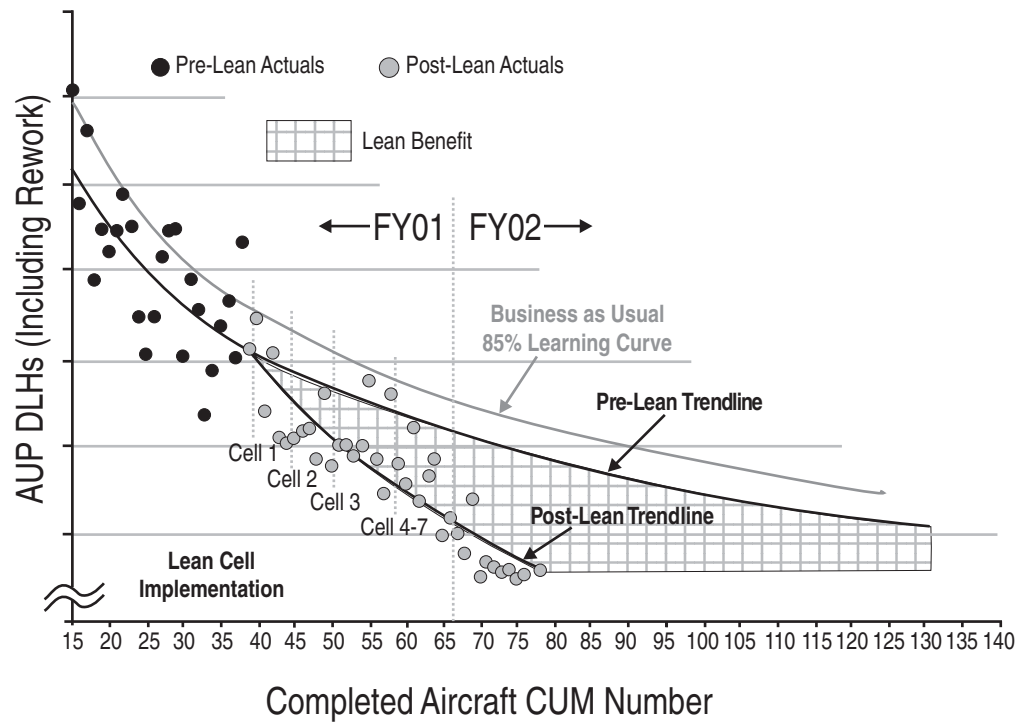


FIGURE 9.
DIRECT LABOR HOURS FOR COMPLETED A/C
DURING LEAN TRANSITION

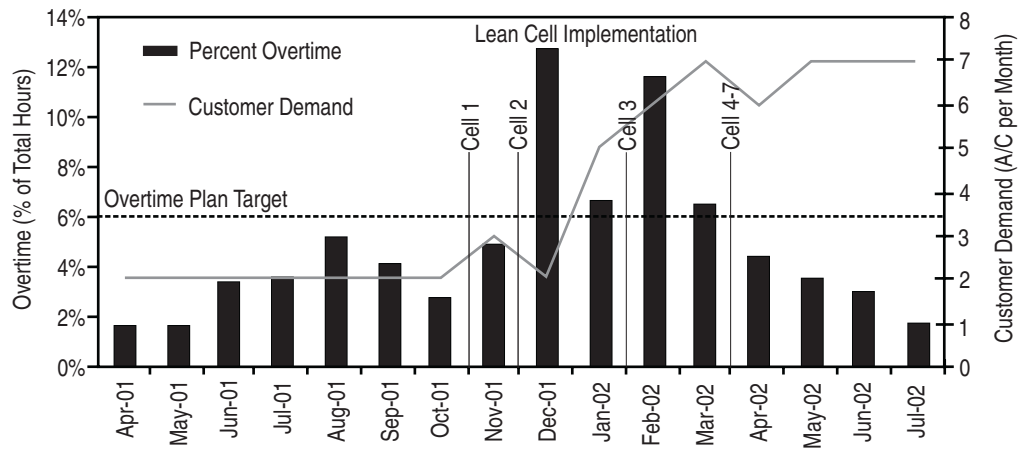


FIGURE 10. OVERTIME PERFORMANCE DURING LEAN TRANSITION

LESSONS LEARNED

Implementing Lean principles is synonymous with changing workforce culture. The workforce, both factory and non-factory alike, perform best when they claim ownership and accountability for their own actions and that of their team. Extending responsibility, authority, and accountability to self-directed work teams (within bounds) invigorates the workforce and fosters creativity. A workplace where everyone's opinion is valued equally and teams are recognized and rewarded for excellence will continuously improve. A successful transition to a Lean enterprise production system is as much about the people and culture transition as it is production flow and reconfiguring brick and mortar.

Implementing Lean principles is a continuous journey. Remain flexible and support adaptive processes. Today's good idea will be replaced by tomorrow's creativity and improvements in technology in an environment of continuous improvement. The T-38C Production System future state was barely 2 years old before it had gone through two significant refinements. The subject matter experts participating in the original 3P event were unable to envision the realm of today's possibilities. It is as if they had to travel down the road of employee involvement and around the corner of continuous improvement before they could see where and how far they could go.

Implementing Lean principles is not free. Training and a willingness to invest in adaptive processes capable of supporting single piece continuous flow TAKT based production are required. However, as much as 90 percent of the system improvement can be accomplished with minimal capital investment. Experience has shown that most Lean initiatives easily surpass a 4.0 return on investment threshold.



David D. Ott began his aerospace career in structures technology with a passion for designing for manufacturing and assembly. His background in definition engineering, materials research, and implementing quality and cost improvement initiatives provides a foundation to guide Lean Implementation throughout the product value stream. As a Lean Enterprise Implementation Specialist, Ott targets improving factory and non-factory processes in order to realize gains in quality and reduced cycle and cost.

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James B. Davis was trained in Kaizen, or continuous improvement, by protégés of Taiichi Ohno, and considers himself to be a student of Lean, seasoned by the school of hard knocks. Recent assignments include Industrial Engineering, Production Support, Process Redesign, Program Management, and Lean in both Commercial and Defense businesses. Davis has a bachelor's degree in finance and economics from Ohio State University, and a master of business administration in international business from Duke University.

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